MERCURIAN CRATER RIM HEIGHTS AND SOME INTERPLANETARY COMPARISONS.

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The study of impact crater rim topography is an important aspect of the investigation of numerous geological problems related to planetary surface processes. In particular, interplanetary comparisons of crater rim shapes could lead to constraints on interpretation of the mechanisms and results of crater-forming processes such as energy partitioning, crater diameter-energy scaling, and cavity modification. Accurate measurements exist for lunar crater rim heights and, with lower confidence, for those on Phobos and Deimos. This report presents data for Mercurian crater rim heights and compares them to statistical samples from these other planetary bodies.

DATA - Mercury: The techniques employed in compiling the Brown University Mercury Crater Library[1] were applied in determining rim heights for 30 mercurian craters through shadow measurements. Each rim height was measured at least 4 separate times; only those craters with shadows extending past the break in slope of the exterior topography were included in this study. These data are presented in Table 1. As is the case for lunar craters,[2] the logarithmic rim height (R_e) vs. crater rim diameter (D_r) plot is described by two linear least-squares fits (divided into two groups at D_r = 18 km on the basis of visual observation which was refined by maximizing correlation coefficients for the two fits), which are illustrated in Figure 1. Moon: The R_e/D_r relationships derived from Apollo photogrammetric data by Pike[2] are utilized here; these are shown in Figure 1. Phobos and Deimos (P&D): R_e/D_r data for 41 craters on the martian moons have been collected from Viking Orbiter photographs.[3] Because of the irregular shapes of these bodies and uncertainties in viewing/lighting geometries, these data are considerably less accurate than those for the Moon and Mercury. A logarithmic least-squares fit has been applied to the Phobos and Deimos R_e/D_r values and is also presented in Figure 1. The expressions for the fits to the three data sets are summarized in Table 2.

DISCUSSION: Analyses of variance (through F-distribution tests) indicate with a high degree of confidence (>99%) that the three samples of R_e/D_r values below the breaks in slope come from separate populations; the larger lunar and mercurian craters, however, cannot be distinguished at the 90% confidence level. Within the limitations of the data, the distributions for the smaller lunar and mercurian craters and those on P&D appear to have slopes of 1, the value expected for landforms whose morphologic elements maintain a constant geometric relationship with increasing size.[4] The slope decrease, on the other hand, represents the transition to shapes which vary with size. According to the least-squares fits, the break in slope occurs at D_r = 16.3 km and R_e = 0.7 km on Mercury, with corresponding values of 21.3 km and 0.8 km for the Moon; no such slope change is apparent in the P&D data. When crater depth (R_i) is plotted against D_r, similar slope transitions occur at D_r = 9.8 km (Mercury)[5] and 10.6 km (Moon),[6] with R_i = 1.6 km and 2.1 km (Mercury and Moon, respectively). The P&D data are again represented well by a single curve.[3,7] In both the lunar and mercurian cases, the break in slope in the R_i/D_r relationship occurs at a smaller D_r than does the slope transition in the R_e/D_r distribution. This indicates that the process(es) which decreases the R_e/D_r ratio is not as effective as that (those) which reduces the R_i/D_r ratio at the smaller diameters. This could be due to one or both of the following possibilities: (A) Wall failure would decrease the R_i/D_r ratio by removing a fraction of the rim component of crater depth while also filling the crater with the slumped wall material; the depth of the original (conical or parabolic) crater will decrease rapidly with the emplacement of relatively small volumes

of wall debris. Only a small reduction in rim topography (which could be "absorbed" by the scatter in the data) would result from the small increase in crater diameter necessary to decrease the depth by minor wall slumping (Figure 2). (B) Crater depth is affected by some mechanism(s), such as target rebound, before the rim height-reducing process takes effect. In any event, the process(es) responsible for the R_e/D_r slope decrease is sufficiently random in magnitude that any differences between the lunar and mercurian samples are lost in the scatter.

Since (a) it appears that the amounts of plastic work done by an impact event decrease with increasing impact velocity (on the basis of cratering models)[8] and (b) impact velocities are higher at Mercury than at the Moon[9] which, in turn, are higher than those at Mars,[10] ejecta should constitute a larger component of the rim height on Mercury than on the Moon and P&D. This sequence whould be aided, coincidentally, by the same trend in surface gravity. The stronger mercurian gravity field should concentrate crater ejecta closer to the rim than would the Moon's weaker field;[11] at the other end of the spectrum, ejecta probably constitutes a negligible fraction of rim topography on P&D.[3,12] Mercury's higher surface gravity and rim elevations should initiate slumping (due to increased rim loading) at smaller crater diameters, make the emplacement of exterior impact melt deposits more difficult, and allow rims to resist impact degradation more effectively than in the lunar case.[13] Although the observed sequence of R_e/D_r ratios is qualitatively consistent with gravitational control of ejecta thicknesses, attempts to quantify structural and ejecta components of lunar and mercurian crater rim topography must be tempered by the possibly significant differences in energy partitioning between different target materials. Hence, although crater rims on P&D might indeed be almost entirely structural in nature, the poorly understood mechanical properties of the two martian moons[12] as yet preclude meaningful extrapolation to the Moon and Mercury.

CONCLUSIONS: Mercurian crater rim heights are greater than those on the Moon, which appear to be greater than those on Phobos and Deimos. This is in qualitative agreement with a direct relationship between surface gravity strength and the magnitude of the ejecta component of rim height. Due to uncertainties in (1) material properties on these bodies and (2) energy partitioning as a function of impact velocity and projectile characteristics, attempts at quantitative evaluation of ejecta and structural components of rim topography appear to be unwarranted with available data.

Table 1. Mercurian fresh crater rim heights; 2 and 3 significant figures on D_r and R_e given for rounding purposes only. 1σ = 1 standard deviation.

$D_r \pm 1\sigma$	$R_e \pm 1\sigma$	LATITUDE	LONGITUDE	NUMBER OF MEASUREMENTS
2.61±0.09	0.065±0.006	-9.98	187.51	4
3.55±0.15	0.132±0.010	-0.81	186.99	6
4.18±0.10	0.241±0.007	-1.31	186.74	7
4.18±0.31	0.190±0.019	-8.95	185.94	8
4.94±0.30	0.240±0.017	30.30	186.74	5
6.15±0.25	0.394±0.011	40.35	185.29	5
6.18±0.16	0.352±0.036	28.97	185.01	5
6.19±0.23	0.302±0.016	76.82	186.39	5
6.49±0.17	0.205±0.010	-9.23	185.17	4
7.50±0.20	0.420±0.037	39.87	186.00	5
8.39±0.24	0.485±0.039	28.15	186.48	4
10.31±0.32	0.395±0.010	84.99	132.65	6
10.41±0.50	0.486±0.021	86.67	92.22	5
10.58±0.15	0.462±0.028	-1.17	186.46	6
10.73±0.20	0.418±0.031	33.51	185.96	5
11.11±0.24	0.317±0.021	42.84	186.06	10
12.20±0.22	0.530±0.028	-10.82	183.86	5
12.47±0.31	0.476±0.050	85.15	128.25	5
12.53±0.35	0.624±0.086	29.13	186.71	9
12.98±0.32	0.499±0.042	31.04	185.26	7
15.29±0.13	0.587±0.022	30.99	184.21	6
18.44±0.21	0.754±0.005	23.08	185.44	5
20.72±0.30	0.786±0.048	24.38	184.07	5
22.81±0.13	0.684±0.057	37.67	186.69	5
27.05±1.09	0.878±0.026	86.45	118.28	4
29.25±0.35	0.906±0.030	24.41	185.78	5
32.64±1.12	1.08 ±0.062	79.38	152.31	6
33.70±0.49	0.925±0.030	26.78	184.25	4
34.48±1.48	0.967±0.076	83.60	145.44	6
38.87±0.63	0.804±0.028	44.59	186.32	10

Table 2. Rim height (R_e) and Depth (R_i) vs. Diameter (D_r) relationships for craters on Mercury, the Moon, and Phobos and Deimos.

PLANET	D_r RANGE	EXPRESSION	STANDARD ERROR*	REFERENCE
Mercury	<9.8	$R_i=0.176\ D_r^{0.980}$	-----	5
	>9.8	$R_i=0.910\ D_r^{0.260}$	-----	5
	<18	$R_e=0.043\ D_r^{1.005}$	±0.109	This paper
	>18	$R_e=0.268\ D_r^{0.349}$	±0.050	This paper
	<15	$R_i=0.196\ D_r^{1.010}$	+0.038 -0.027	2
Moon	>15	$R_i=1.044\ D_r^{0.301}$	+0.067 -0.063	2
	<15	$R_e=0.036\ D_r^{1.014}$	+0.0075 -0.0062	2
	>15	$R_e=0.236\ D_r^{0.399}$	+0.036 -0.031	2
Phobos/Deimos	$\lesssim$10	$R_i=0.2\ D_r$	-----	7
	$\lesssim$10	$R_e=0.017D_r^{0.975}$	±0.287	Data from 3

*Given as the standard error of R_x on D_r; from a fit of the form $\log_{10}R_x = \log_{10} a + b\ D_r$.

MERCURIAN CRATER RIM HEIGHTS

Cintala, M.J. and Head, J.W.

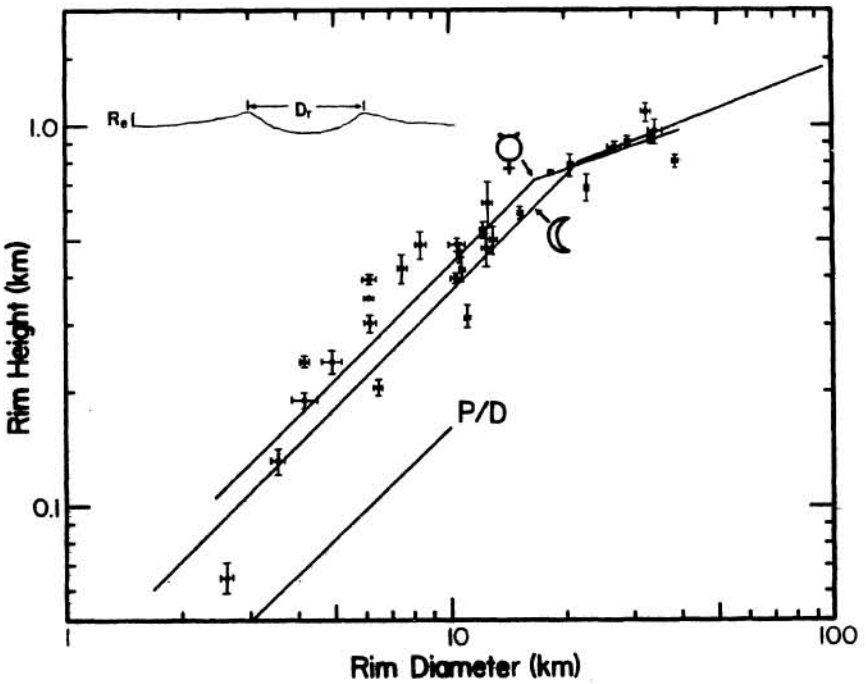

Figure 1. Rim height vs. crater diameter (R_e vs. D_r) for fresh mercurian craters. Error bars represent 1 standard deviation in R_e and D_r measurements. R_e/D_r least-squares fits for craters on Mercury, the Moon, and Phobos and Deimos(P/D) are also illustrated.

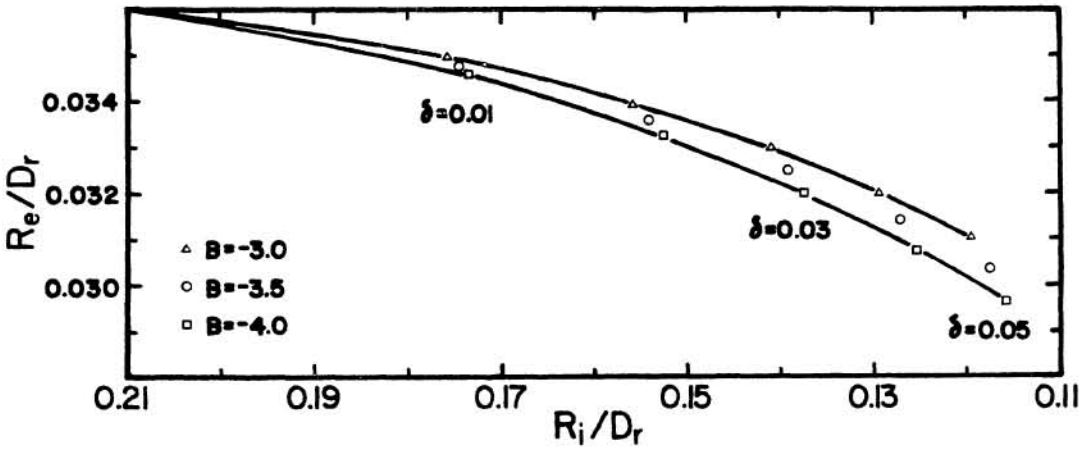

Figure 2. Model results illustrating the relative rates of decrease in R_e/D_r and R_i/D_r as a function of increase in crater diameter ($\delta = \Delta D_r/D_r$) due to wall slumping. B comes from the hypothetical relationship describing the radial decay of rim topography: $h = R_e(d/D_r)^B$, where h = exterior elevation at distance d from the crater rim (see 14). The model assumes that all slumped material is spread evenly over the crater floor; initial wall slope = 30°. For all three values of B, the R_i/D_r ratio decreases much more rapidly than the R_e/D_r ratio.

References: [1]Cintala, M.J. et al. (1976) Conf. Compar. Merc. Moon, p. 5 (abs); [2]Pike, R.J. (1977) Impact and Explosion Cratering, p. 489; [3]Thomas, P.C. (1978) Ph.D. Thesis, Cornell Univ., 272 pp.; [4]Pike, R.J. (1968) Ph.D. Thesis, Univ. Michigan, 404 pp.; [5]Malin, M.C. and D. Dzurisin (1977) JGR 82, p. 376; [6]Pike, R.J. (1974) GRL 1, p. 291; [7]Veverka, J. et al. (1977) Bull. Amer. Astron. Soc. 9, p. 517; [8]O'Keefe, J.D. and T.J. Ahrens (1977) Proc. Lunar Sci. Conf. 8th, p. 3357; [9]Wetherill, G.W. (1975) Proc. Lunar Sci. Conf. 6th, p. 1539; [10]Hartmann, W.K. (1977) Icarus 31, p. 260; [11]Gault, D.E. et al. (1975) JGR 80, p. 2444; [12]Cintala, M.J. et al. (1978) Proc. Lunar Planet. Sci. Conf. 9th; in press; [13]Head, J.W. et al. (1976) Conf. Compar. Merc. Moon, p. 15 (abs); Wood, C.A. et al. (1977) Proc. Lunar Sci. Conf. 8th, p. 3503; [14]Settle, M. and J.W. Head (1977) Icarus 31, p. 123.